Modelling the Scottish Hydropower Resource

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N. Duncan, G.P. Harrison, A.R. Wallace
Institute for Energy Systems, School of Engineering, University of Edinburgh, Edinburgh, United Kingdom, EH9 3JL. n.j.duncan@ed.ac.uk

Introduction

Scotland has a long history of exploiting its hydropower potential and, with aggressive targets for renewable energy set by the Scottish Government, interest in this resource is resurgent. Little research has been conducted to investigate the potential climate impacts upon the resource, however. Climatologies developed by the United Kingdom Meteorological Office (UKMO; Hollis et al, 2004) for the standard periods 1961-1990 and 1971-2000 show an interdecadal reduction in days of the year with lying snow. Snowmelt plays an important role in the operation of Scottish hydro schemes, effectively providing additional storage capacity, smoothing out winter/spring runoff allowing improved capacity factors.

Method

To allow a more complete study of the temporal distribution of the resource, including recent climate impacts upon snowfall and snowmelt, a grid based distributed deterministic rainfall-runoff model has been applied Scotland-wide to simulate daily average river flows. The model makes use of both historic gridded daily rain gauge and temperature data to allow snowfall and snowmelt to be modelled. Called the "Grid-to-Grid Model" or G2G, the model was developed by CEH Wallingford (Bell V.A. et al, 2007) to make use of gridded meteorological and GIS based datasets. As the model is designed to make distributed flow predictions it is well suited for use in a hydropower resource assessment.

The model was forced using a daily gridded rainfall dataset derived from gauged rainfall data (UKMO, 2007) covering Scotland for the period 1960-2005 and an elevation weighted daily gridded temperature derived from a dataset produced by the ENSEMBLES project. Gridded monthly evapotranspiration was computed using the Penman Monteith method based upon gridded UKMO data made available by the UK Climate Projections (UKCP09) project. An elevation corrected snowmelt model utilising a water budget and degree day method was used to model snowfall and melt.

The model was implemented in optimised C++ code allowing a high resolution grid size of 250m. This high resolution has made it possible to produce long-term simulated hydrographs (see Figure 1) and flow duration curves at frequent intervals for the vast majority of reaches in Scotland's river network.

Results

Catchments were modelled with and without the snowmelt model, it was found that when included, overall model performance for upland catchments with significant annual snowcover was greatly improved, giving confidence in the snowmelt model's ability to represent both volumes and timing of snowfall and snowmelt.

To enable the model to be used country-wide and effectively simulate ungauged catchments the model was calibrated over multiple catchments to produce a single set of parameters. Six geographically dispersed catchments were chosen, and optimised parameter settings found using the mean goodness of fit across the catchments as an objective function.

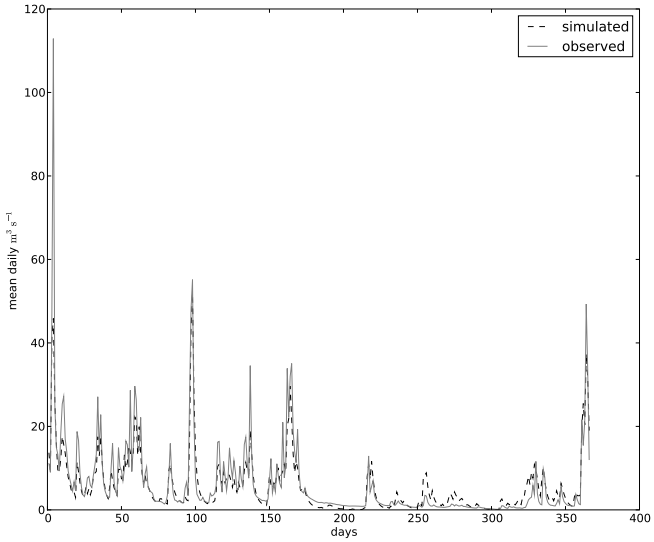

Figure 1 Simulated hydrograph for Girvan catchment for 1982

Future Work

The development of a high resolution distributed hydrological model with a country wide calibration will allow an analysis of the temporal variance of the resource from season to season and year to year, including interdecadal changes to snowmelt patterns as identified by the UKMO. Future work will focus upon developing a multi-parameter 'hydro-search algorithm' which will use the simulated hydrographs and derived flow duration curves as input in conjunction with a suitable elevation model.

References

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